

Caribou and the Kanuti National Wildlife Refuge Lichen Protection Zone -- 2012

Tim Craig and Anna-Marie Benson



Introduction

Barren-ground caribou (*Rangifer tarandus granti*) are an important wildlife species in Alaska because they provide sustenance to humans, as well as less tangible cultural benefits (Rupp et al. 2006). They are also considered a keystone species (i.e. one having a disproportionate impact on many other species) in the Arctic ecosystem (Johnson et al. 2005). Because much of interior Alaska is *de facto* wilderness, caribou and their habitats have largely escaped the direct human-caused perturbations noted elsewhere (Festa-Bianchet et al. 2011). However, climate change is predicted to have strong influences on biotic systems in the future, particularly at high latitudes (Chapin et al. 1995, Lawler et al. 2009). In the northern part of interior Alaska, these changes are predicted to include an appreciably warmer and drier climate by the end of this century that will likely be accompanied by an increase in wildfire occurrence and severity (Rupp and Springsteen 2009). Among related ecological effects of these changes are declines in terricolous lichen, both due to changes in growing conditions (Joly et al. 2009; Chapin et al. 1995) and increased mortality of lichen communities due to wildfire (Collins et al. 2011).

Caribou in Alaska depend on terricolous lichen for winter forage (Joly et al. 2012). Joly et al. (2010) have shown there can be four times the abundance of these lichens in unburned (i.e. sites > 58 years post burn) than burned sites within the winter range of the Western Arctic Caribou Herd in western Alaska. Caribou tend to avoid burned sites until 50-60 years have pass because lichens are so slow to recover after wildfire (Joly et al. 2009). In fact, Jandt et al. (2008) have shown there can be less than 5% lichen cover

on burned tundra sites even after 35 years post burn. Similarly, Collins et al. (2011) found that animals from the Nelchina Caribou Herd select areas with greater abundance of terricolous lichens than other sites in the taiga; they too hypothesize that caribou avoid burned habitat due to lower availability of lichens. Similar findings elsewhere in the boreal forest indicate that caribou avoid these burned areas for decades (Joly et al. 2007) leading to shifts in winter range use by caribou (Schaefer and Pruitt 1991, Joly et al. 2010).

Caribou have not regularly been resident on the Kanuti National Wildlife Refuge (hereafter, Kanuti NWR or the Refuge) since it was established in 1980. However, animals from the Western Arctic (WAH) or the nearby Ray Mountains Herd periodically winter on the Refuge (Alaska Department of Fish and Game 2009, Kanuti NWR unpubl. files). The number of caribou occurring on Kanuti NWR has been very low since 2000, with the exception of winter 2004 when approximately 1,000 caribou wintered on the Refuge. In contrast, caribou were historically an important part of the Refuge ecosystem and a prominent subsistence resource for nearby villages. Local Traditional Ecological Knowledge is that caribou use of the Refuge, particularly on the Kanuti Flats, was greater in the past when large herds of what were assumed to be Western Arctic Herd caribou migrated down the John River and on to the Refuge during winter. For example, an estimated 60,000 animals crossed the Kanuti Flats in early winter 1992, 2,000 of which remained on the Refuge until late winter 1993 (USFWS 1993). Indeed, one of the establishment purposes of the Refuge under the Alaska National Interest Land Conservation Act (Public Law 96-487 (94 Stat. 2371)) is:

“To conserve fish and wildlife populations and habitats in their natural diversity, including but not limited to...caribou (including participation in coordinated ecological studies and management of the Western Arctic caribou herd)...”

Drawing on this direction, the Kanuti NWR Comprehensive Conservation Plan (USFWS 2008) and Fire Management Plan (USFWS 2007) established as goals to:

- Document winter abundance and distribution of caribou through monthly reconnaissance flights.
- Provide increased fire protection for lichen habitat used as range by wintering caribou... in the central portion of the Refuge where there had been no recorded wildfires since 1942.

The later goal resulted in establishment of a Lichen Protection Zone (LPZ), a 30,000 ha area where the fire management objective is to maintain terricolous lichens. While these Refuge goals are both ostensibly aimed at protecting winter caribou habitat, they also address the Refuge goal of conserving natural diversity since unburned, old, open, spruce forest that is underlain by lichens will be conserved along with its associated biota.

Satellite radio-telemetry data provided by the Alaska Department of Fish and Game (ADFG) and the National Park Service revealed that WAH caribou moved onto the Refuge in November 2011. Two, and sometime three, of these satellite radio-collared animals stayed on the Refuge throughout the winter of 2012. The winter distribution of caribou is not even, being influenced by both biotic and abiotic factors (Joly 2011); therefore, caution must be used when estimating the number of animals that use an area based on the number of radio-collars present. However, by comparing the number of satellite radios on the Refuge to the number deployed on WAH animals (95) in relation to the number of animals in the herd (325,000), we estimated that over 6,000 caribou could be on the Refuge in winter 2011- 2012. Therefore, in late winter Refuge staff began reconnaissance flights to determine the actual magnitude of the influx in parts of the Refuge (Table 1).

The reconnaissance flights were conducted in association with other tasks and were not uniformly distributed across the Refuge. Nonetheless, they indicated that many caribou occupied the Refuge (Fig. 1), and lead to a survey near Lake Todatonten (Dillard 2012) and the systematic survey described in this report. While none of the reconnaissance flights were designed to yield absolute population estimates, they do provide information on caribou use and distribution in the greater area. Signals from ADFG's satellite collars indicated that the caribou with collars moved west off the Refuge between mid-May and Mid-June. Interestingly, Refuge staff observed several pregnant cows (they carried hard antlers) on the Refuge in the vicinity of Kanuti Lake as late as mid-May, and even observed a cow with a newborn calf there on 26 May.

Table 1. Caribou sightings made during reconnaissance flights on and near Kanuti National Wildlife Refuge, Alaska, Spring 2012.

Date	Sightings	Location
2/5/2012	204	Kanuti Flats/ LPZ
2/6/2012	717	Kanuti Flats/LPZ and SW Refuge
3/1/2012	450	Kanuti Flats/LPZ
3/2/2012	300	Kanuti Flats/LPZ
3/7/2012	5 + 4 Feeding sites	North-central Refuge
3/9/2012	42 + 7 Feeding sites	Kanuti Flats/LPZ and SW Refuge
4/2/2012	260	Kanuti Flats/LPZ
4/9/2012	37	Kanuti Flats/LPZ
4/13/2012	1390	Kanuti Flats/LPZ
4/15/2012	840	Kanuti Flats/LPZ
4/17/2012	757	High altitude reconnaissance of Refuge (estimate)
4/17/2012	233	Lake Todatonten systematic survey

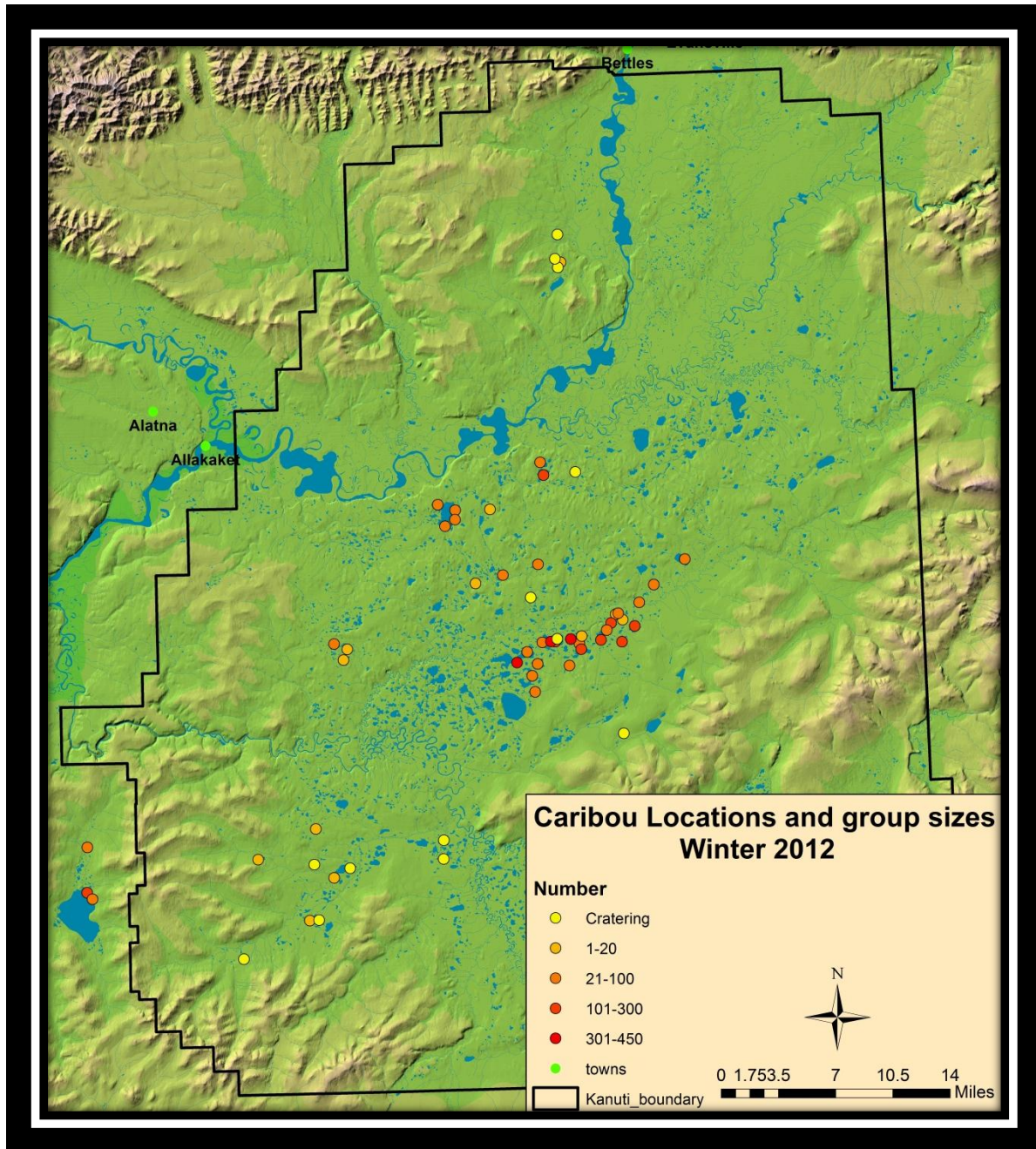


Figure 1. Caribou group locations and sign (cratering) observed during 10 reconnaissance flights on Kanuti National Wildlife Refuge, Alaska, and a survey conducted around Lake Todatonten, Alaska from February through April, 2012.

During reconnaissance flights, we noted that caribou were concentrated in or near the Lichen Protection Zone. Therefore, we designed a sampling scheme to estimate habitat use by wintering caribou in its general vicinity in three different ecological strata that were based on fire history (Figure. 2). We used these data to compare caribou use of unburned and recently burned areas. We also sampled a larger area that included all three strata in order to estimate the size of the caribou population in this study area.

Specific objectives of the study were to:

1. Determine whether wintering caribou disproportionately selected unburned habitat (LPZ) relative to other nearby parts of the Refuge with similar physiography, but different fire histories.
2. Provide baseline information to monitor inter-annual changes in wintering caribou numbers in three different ecological strata and an area that contains all three strata on the Refuge.
3. Provide information to management so that informed decisions can be made when formulating regulations and policies and allocating resources when fires threaten lichen-rich communities on the Refuge.

Study Area

The Kanuti NWR boundary circumscribes about 526,000 ha, most of which (over 81%) falls within the “Kobuk Ridges and Valleys” ecoregion (Nowacki 2001), a series of paralleling ridges and valleys radiating southward from the Brooks Range. The climate in the area is strongly continental (Hartman and Johnson 1978) and is characterized by short, warm summers and long, dry, cold winters. The average annual temperature for the warmest month of the year (July) was about 15° C at a nearby weather station in Bettles, Alaska, and the average annual temperature for the coldest (February), -22° C (<http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?ak0761>). The average annual precipitation at this station was about 36 cm and the average monthly winter snow depth, 66.5 cm.

Vegetation on the Refuge is typical of the northern boreal forest: black spruce (*Picea mariana*) occurs in wetland bogs, white spruce (*Picea glauca*), paper birch (*Betula papyrifera*), and balsam poplar (*Populus balsamifera*) grow along rivers, white spruce, paper birch, and trembling aspen (*Populus tremuloides*) stands occur on well-drained uplands, and tall and short shrublands of willow (*Salix* spp.), birch (*Betula* spp.), and/or alder (*Alnus* spp.) grow on the ridges. Mats of terricolous lichens are common where the absence of fire has allowed old-growth black spruce to persist.

Fire is the dominant disturbance factor in the area and the Refuge has a rich fire history (USFWS 2008). Nearly 404,000 ha have burned on Kanuti NWR since 1990 (USFWS 2008). Much of the remaining unburned area lies in a contiguous, relatively narrow band in the central portion of the Refuge. Part of this unburned portion of the Refuge was identified during aerial reconnaissance as being replete with terricolous lichens. On the basis of this reconnaissance, Refuge management designated 30,000 ha of this area as a Lichen Protection Zone (LPZ) in 2007.

Our study area was a square 139,403 ha area that lies in the central portion of the Kanuti NWR (Fig. 1) and encompassed the Lichen Protection Zone. Within this polygon, there were areas that have not been documented to have burned since 1942 when fire history records for the Refuge begin, and areas that have burned at different times in the past: 1972, 1990, 1991, 1999, and 2004.

Methods

During this aerial survey we counted caribou and/or categorized caribou activity in 38 sample units (SU). The sample units we used are a subset of cells from a grid used in the Geo-Spatial Population Estimator (GSPE) developed for surveying moose by Alaska Department of Fish and Game (Kellie and DeLong 2006). Each sample unit is a four-sided polygon, 2 minutes of latitude on two sides, and 5 minutes of longitude on the other sides. Within our study area, these sample units are about 13.7 km² (1385 ha) each.

We selected 11 contiguous sample units in the Lichen Protection Zone where no recorded fire had occurred since 1942 to represent one ecological stratum. For the purposes of this document, we consider the LPZ and other old-growth spruce/lichen habitat to be “unburned” even though these areas have undoubtedly burned sometime in the past. We located seven other units in each of two areas where wildfires occurred in 1972 and 2004; the latter sample stratum was within an area originally designated as a Lichen Protection Zone in 2006, but that had burned in a wildfire in 2004. Sample units within each of the three strata were mostly contained within fire perimeter boundaries, although the boundaries of a few of the sample units overlap fire perimeter boundaries. In addition to surveying caribou activity in these three ecological strata, we selected 18 sample units (20% of the total) within a larger area (a 90 sample unit block) that included all three strata in order to estimate the total number of animals in the general area. These units were randomly selected from all of the units in the survey block, including the 3 ecological strata sample areas.

We conducted the survey in early March, after we had confirmed the presence of wintering caribou during reconnaissance flights over the Refuge. We surveyed each sample unit within the different strata in the same manner. We used two tandem-seated airplanes (an American Champion Scout and an Aviat Husky) with a pilot and backseat observer in each. The two-person survey teams flew parallel lines back and forth within each sample unit boundary, counting all of the caribou they encountered within the unit. Aircraft deviated from these lines to circle and enumerate caribou when necessary. The pilot in each plane was responsible for observing caribou on one side of the airplane, navigating via the airplane's Global Positioning System unit and flying the plane. The backseat passenger was responsible for observing caribou on the opposite side of the plane and recording data.

One plane searched 15 sample units on 8 March, while the second plane searched 5, 13 and 5 units on 7, 8 and 9 March, respectively. We recorded conditions as “good” to “excellent” throughout the survey, i.e. there was good light and fresh, or nearly fresh, complete snow cover. We surveyed units at 80 kt./hr (cruise speed) and at an altitude of about 150m. Each survey plane thoroughly searched assigned sample units, but the time spent in units varied depending on the complexity of the vegetation and level of caribou activity encountered. The airplanes spent a mean of 24.7 min \pm 4.5 (SD; range = 15- 37 min) in each unit.

During the survey, we recorded each caribou observed and the total number of groups of caribou we spotted. During winter, when caribou feed predominately on terricolous lichens (Holleman et al. 1979), they uncover the lichens by pawing the snow, creating obvious “craters” (Telfer and Kelsall 1984, Pruitt 1959). Therefore, to gain a sense of caribou use of an area when no animals were present, we recorded the intensity of the cratering and trails we observed in a sample unit, or a large part of a unit, in one of three categories: Low, Moderate and Extensive. Our categorization of caribou activity evolved as the study progressed. Therefore, we could not statistically analyze these data. Nonetheless, we present the results in tabular form. We documented examples of each activity category with photos to ensure that observers in future surveys consistently record caribou activity in the proper category (Appendix 1). Due to the presence of unburned inclusions within the burn perimeters, we also recorded whether animals or their sign appeared to be in burned or unburned habitat when we surveyed the burned strata.

We planned to develop a “Gasaway-style” “sightability correction factor during our survey (Kellie and DeLong 2006), but the quadrats we randomly selected to be intensely surveyed as part of this technique contained no caribou during the survey. Because our detection of caribou was likely not absolute, the true parameter measured during our survey was the number of *observable* caribou, i.e., all caribou *not* obscured by dense cover.

Economic considerations and aircraft use limitations required us to conduct the survey over three days. However, the analysis assumes that there is no significant caribou emigration from, or immigration into, different sample units during the course of the survey. To reduce the chance of animals moving between units, we clumped sample units that we surveyed together on each day, and, with the exception of two adjacent sample units, we kept a separation of at least 3.7 km between sample units that we surveyed on different days.

Statistical Analysis

Modeling Presence/Absence of Caribou--We ran several models to determine whether stratum, shoreline area (ha), the type of airplane used in surveying, or the time spent searching individual sample units influenced our ability to predict the presence or absence of caribou activity and the number of caribou counted within a sample unit. Shoreline area was selected after considering two other correlated variables (number of lakes and acres of lakes) because previous studies indicated that caribou forage along lake edges (Pruitt 1959, Carruthers et al. 1986, Ferguson and Elkie 2005).

We used a logistic model to predict the presence or absence of caribou where we recorded the presence of caribou, or noted sign that caribou had used a sample unit. The probability of detecting at least one caribou was modeled using the logit link:

$$\begin{aligned}\text{logit}(p_i) &= \beta_0 + \beta_1(\text{Strata}) + \beta_2\text{Shoreline} + \beta_3\text{Time} + \beta_4\text{Aircraft} && \text{(Full Model)} \\ \text{logit}(p_i) &= \beta_0 && \text{(Null Model)}\end{aligned}$$

Where:

p_i is the probability of detecting caribou at the i^{th} sample unit

Strata were: 1.) LZP (not burned), 2.) burned in 1972, and 3.) the original LPZ that burned in 2004

Shoreline (length in meters)

Time was the amount of time spent surveying the sample unit

Aircraft was a Husky or Scout aircraft

Modeling total count of caribou--We used a Poisson model for the count data (number of caribou counted on each strata). These count data were overdispersed, i.e., the mean was much bigger than the variance, because we observed a wide range of counts of individuals and recorded a large number of zero counts. Because the data exhibited these properties, we used a Zero-Inflated Poisson Model (ZIP). The ZIP model has two components: a count model, which allowed us to evaluate whether several variables predicted caribou counts (strata, shoreline, search time, and aircraft used during the survey), and the zeros are modeled separately using a logit model

$$\begin{aligned}\log(\text{count}_i) &= \beta_0 + \beta_1(\text{Strata}) + \beta_2\text{Shoreline} + \beta_3\text{Time} + \beta_4\text{Aircraft} && \text{(Full Model)} \\ \log(\text{count}_i) &= \beta_0 + \beta_1(\text{Strata}) && \text{(Strata Model)} \\ \log(\text{count}_i) &= \beta_0 && \text{(Null Model)}\end{aligned}$$

To obtain a population estimate for the general area, we randomly sampled 20% of the sample frame (18 of the 90 sample units), about 24,930 ha of the entire study area (124,650 ha). We determined an average

count of caribou per unit used a nonparametric bootstrap approach to obtain a 90% confidence interval around the mean number of caribou/sample unit, and extrapolated this average to the whole sample area.

Results

We counted a total of 1,841 caribou during the three-day survey. We found that wintering caribou were disproportionately distributed across the three strata surveyed ($X^2 = 2,705$, $df = 2$, $P < 0.001$); caribou counts were highest in the Lichen Protection Zone (Table 2). We also found more caribou activity in units located within the unburned stratum than in either of the burned strata (Table 3). Similarly, the survey teams recorded more incidents of extensive activity in the unburned stratum.

Table 2. Number of sample units, caribou, mean caribou/sample unit, and caribou activity level in sample units in different ecological strata on Kanuti National Wildlife Refuge, Alaska, March 2012.

Strata	No. of sample units	No. caribou sighted	Mean (caribou/sample unit)	No. of units with caribou sign but without caribou	Activity Level in sample units with caribou sign, but without caribou		
					Low	Moderate	Extensive
Lichen Protection Zone	11	1501	136	10	0	2	8
Burned in 1972	7	70	10	1	0	0	1
Burned in 2004	7	9	1	7	2	2	3
Other units surveyed	13	261	20	10	1	4	5
Total	38	1841	49	28	3	8	17

Table 3. Number of caribou and number of incidents of caribou activity in habitat identified as burned or unburned in sample units that were at least partly within wildfire perimeter boundaries on Kanuti National Wildlife Refuge, Alaska, March 2012.

Habitat	No. caribou	Incidents of Extensive caribou use	Incidents of Moderate caribou use	Incidents of Low caribou use
Burned	50	12	35	13
Unburned inclusion	279	33	31	24
Riparian (includes other 2 habitats)	122	11	13	10

Modeling presence/absence of caribou. Results from the logistic models predicting the probability of detecting caribou showed that the model with a Strata covariate had the best fit for the data (Table 4). Using the Strata model (Table 5) we estimated the probability (p) of detecting a caribou ($p = 0.91$ for the

Lichen Protection Zone, $p = 0.14$ for the 1972 burn strata, and $p = 1.0$ for the 2004 burn strata– the original Lichen Protection Zone that burned in 2004). However, it should be noted that in the 2004 burned strata, caribou used every sample unit, even if most of the activity was not extensive.

Table 4. Ranking of models used to predict the probability of detecting caribou on a 90sample unit survey area on Kanuti National Wildlife Refuge, Alaska, March 2012. Covariates are ordered from best fit to worst fit using Akaike’s Information Criteria corrected for small sample sizes (AICc).

Models	K ¹	AICc	Delta_AICc	AICcWt ²	Cum.Wt ³	LL ⁴
Strata	3	19.6	0.0	0.7	0.7	-6.2
Strata+Shoreline	4	22.4	2.8	0.2	0.8	-6.2
Strata+Shoreline+Time	5	23.2	3.6	0.1	0.9	-5.0
Strata+Shoreline+ Aircraft	5	25.5	5.9	0.0	1.0	-6.2
Strata+Shoreline+Time+Aircraft	6	26.7	7.1	0.0	1.0	-5.0
Strata+Shoreline+Strata*Shoreline	6	28.0	8.4	0.0	1.0	-5.7
Null	1	31.8	12.2	0.0	1.0	-14.8
Shoreline	2	34.2	14.6	0.0	1.0	-14.8

¹ K= number of parameters

² AICcWt = AICc weight

³ Cumulative AICc weight

⁴ LL= model loglikelihood

Table 5. Parameter estimates for the Strata model used to predict the probability of detecting the occurrence of caribou among three strata on Kanuti National Wildlife Refuge, Alaska, March 2012.

	Estimate	Std.Error	z-value	Pr(> z)
Intercept (β_0)	2.303	1.049	2.195	0.02813
1972 Strata(β_1)	-4.094	1.506	-2.72	0.00654
2004 Strata(β_2)	17.263	4064.635	0.004	0.99661

The parameter estimates in Table 5 are used to obtain the estimates of probability of detection using the following equations:

$$p_{LPZ} = \frac{\exp(\beta_0 + \beta_1(0) + \beta_2(0))}{1 + \exp(\beta_0 + \beta_1(0) + \beta_2(0))} = \frac{\exp(2.303)}{1 + \exp(2.303)} = 0.91$$

$$p_{1972} = \frac{\exp(\beta_0 + \beta_1(1) + \beta_2(0))}{1 + \exp(\beta_0 + \beta_1(1) + \beta_2(0))} = \frac{\exp(2.303 - 4.094)}{1 + \exp(2.303 - 4.094)} = 0.14$$

$$p_{2004} = \frac{\exp(\beta_0 + \beta_1(1) + \beta_2(0))}{1 + \exp(\beta_0 + \beta_1(1) + \beta_2(0))} = \frac{\exp(2.303 + 17.263)}{1 + \exp(2.303 + 17.263)} = 1.0$$

Count Models. For the count data, most models did not converge; however, parameter estimates were obtained for the null model and the habitat strata model. The habitat strata model fit the data better than the null model ($G^2=637.21$, $df=4$, $P < 0.0001$) indicating that the habitat strata covariate was an important predictor of caribou counts. However, the goodness of fit test indicated that the habitat strata model was not useful for making predictions because of “lack of fit”. Therefore, although we demonstrate that Strata

was an important predictor of caribou counts, the model is not robust enough to predict caribou counts in SUs that were not sampled.

Total observable caribou. We counted a total of 1,841 caribou during the survey; this can be regarded as a minimum count of caribou in our study area and the Refuge. Of these caribou, we counted 531 individuals in 18 sample units that we randomly selected in order to make a population estimate for the entire 90 sample unit study area. The average number of caribou in these 18 units was 29.5 (± 20.61) caribou/sample unit. We applied this mean density across the 90-unit sample frame and obtained a crude estimate that 2,655 (90% confidence interval = 1,841 – 4,513) caribou occupied the study area during our survey.

Discussion

After wildfire, recovery of lichen to levels of abundance sufficient to attract caribou can take over 50 years in Alaska (Collins et al. 2011; Joly et al. 2012). The Lichen Protection Zone remains the last, large stand of old-growth spruce/lichen habitat on Kanuti Refuge. Our results indicate that wintering caribou preferentially selected the Lichen Protection Zone over two other nearby habitats that burned within the past 40 years. It should be noted that we did find that caribou used habitat within the identified burned strata, too. However, because our time in each sample unit was brief, and the available burned area maps are at a coarse scale, we do not know whether these caribou were simply moving through inappropriate habitat, or if they occupied unburned inclusions within the burned area polygons that were not obvious from the air. Similarly, the concentration of caribou craters and trails that we observed in SUs may have been related to the number of caribou in bands that move through a unit, rather than a measure of how important the SU was to caribou for foraging.

In addition to the availability of lichen, winter range occupancy by caribou is strongly influenced by snow depth and hardness. Researchers have observed that in taiga, caribou do not use areas as feeding sites where snow depths are greater than 50-60 cm (LaPerriere and Lent 1977). Furthermore, Fancy and White (1985) found that the energy caribou expend to dig through hard snow is much greater than where snow is loose. The snow depth at three sites in our study area averaged 52 cm in March 2012 and may have neared the maximum snow depth for winter occupancy by caribou.

Thomas et al. (1996) and Carruthers et al. (1986) suggest that caribou select habitat where they have good visibility, such as lakes, in order to avoid predators, and also because travel is relatively easy there. Like others (Pruitt 1959, Carruthers et al. 1986, Ferguson and Elkie 2005), we noted that caribou tended to forage along lake edges during our survey. However, models that included shoreline length did not fit the data as well as models that did not include this variable. The clumped and variable distribution of caribou across our study area likely contributed to the difficulty in modeling this variable.

The population estimate of 2,655 (90% confidence interval = 1,841 – 4,513) caribou should be viewed with caution because the confidence intervals are large, indicating an imprecise estimate. This crude estimate was used because our Poisson models did not have adequate “fit” to model the effect of habitat strata on the count of caribou. The lack of fit is likely caused by the “clumpiness” of the distribution of caribou in our study area. This estimate should not be applied beyond our sample frame because it does not account for factors known to influence the occurrence of caribou (e.g., habitat type).

Cameron et al. (1984) recommended 33% coverage of a study area in order to obtain robust population estimates with useful confidence limits. Because we had limited funds, we were not able to survey the entire Refuge or even the entire study area. Rather, we sampled 20% of our study area, which was itself a small part of Kanuti NWR. Therefore, our results have a narrow inference, but they do provide the first population estimate of caribou in an area that we actively conserve through fire management prescription.

We recommend that this survey be conducted whenever large groups of wintering caribou are detected on the Refuge. As of 2012, the units that we surveyed occurred within the perimeters of fires that burned 7, 22, and 40 years ago. As the lichens in these burns recover, we expected that wintering caribou will begin to use them again, and management direction for the area will need to be reconciled to these changes.

Acknowledgements. Peter Butteri, Erin Julianus, Lisa Saperstein, and Mike Spindler reviewed the report. Mike Spindler, Les Dillard and Mike Hinkes helped conduct the fieldwork. Peter Butteri and Sheila Dufford completed the GIS map-making work.

Literature Cited

Alaska Department of Fish and Game. 2009. Caribou management report of Survey-inventory activities 1 July 2006-30 June 2008. P. Harper, editor. Juneau, Alaska.

Cameron, R.D., K. Whitten, W.T. Smith and D. J. Reed. 1984. Sampling errors associated with line-transect surveys of caribou. Proc. Second N. Am. Caribou Workshop. McGill Subarctic Research Paper Series.

Carruthers, D.R., S.H. Ferguson, R.D. Jakimchuk, and L.G. Sopuck. 1986. Distribution and habitat use of the Bluenose caribou herd in mid-winter. *Rangifer* 1 (Special Issue):57–63.

Chapin, F. S., III, G. R. Shaver, A. E. Giblin, K. J. Nadel-hoffer, and J. A. Laundre. 1995. Responses of arctic tundra to experimental and observed changes in climate. *Ecology* 76: 694-711.

Collins, W. B., B. W. Dale, L. G. Adams, D. E. McElwain, and K. Joly. 2011. Fire, grazing history, lichen abundance, and winter distribution of caribou in Alaska's taiga. *J. Wildl. Manage.* 75:369-377.

Dillard, L. 2012. Aerial caribou survey on and around Lake Todatonten SMA and Kanuti National Wildlife Refuge -- April 17, 2012. USFWS Kanuti National Wildlife Refuge, unpublished report. 8pp.

Fancy, S. G. and R. G. White. 1985. Energy expenditures by caribou while cratering in snow. *J. Wildl. Manage.* 49:987-993.

Ferguson, S.H. and P. C. Elkie. 2005. Use of lake areas in winter by woodland caribou. *Northeastern Naturalist* 12:45-66.

Festa-Bianchet M., J.C. Ray, S. Boutin, S.D. Côté, and A. Gunn. 2011. Conservation of caribou (*Rangifer tarandus*) in Canada: an uncertain future. *Can. J. Zool.* 89:419–434

Hartman, C.W. and P. R. Johnson. 1978. Environmental atlas of Alaska. Institute of Water Resources, University of Alaska, Fairbanks. 95pp.

Holleman, D. F. , J. R. Luick and R..G. White. 1979. Lichen intake estimates for reindeer and caribou during winter. *J. Wildl. Manage.* 43:192-201.

Johnson, C. J., M. S. Boyce, R. L. Case, H. D. Cluff, R. J. Gau, A. Gunn and R. Mulders. 2005. Cumulative Effects of Human Developments on Arctic Wildlife. *Wildlife Monographs* , No. 160. 36 pp.

Kellie, K.A. and R.A. DeLong. 2006. GeoSpatial survey operations manual. Alaska Department of Fish and Game, Fairbanks, Alaska. 55 pp.

Jandt, R. R., K. Joly, C. R. Meyers and C. Racine. 2008. Slow recover of lichen on burned caribou winter range in Alaska tundra: potential influence of climate warming and other disturbance. *Arctic, Antarctic and Alpine Research* 40: 89-95.

Joly, K., 2011. Modeling influence on winter distribution of caribou in northwestern Alaska through use of satellite telemetry. *Rangifer* # 19 (Special Issue): 75-85.

Joly, K., B. W. Dale, W. B. Collins, and L. G. Adams. 2003. Winter habitat use by female caribou in relation to wildland fires in interior Alaska. *Can. J. Zool.* 81:1192–1201.

Joly, K. F. S. Chapin III and D. R. Klein. 2010. Winter habitat selection by caribou in relation to lichen abundance, wildfire, grazing and landscape characteristics in northwest Alaska. *Ecoscience* 17: 321-333.

Joly, K., P. A. Duffy, and T. S. Rupp. 2012. Simulating the effects of climate change on fire regimes in Arctic biomes: implications for caribou and moose habitat. *Ecosphere* 3(5):36.
<http://dx.doi.org/10.1890/ES12-00012.1>

Joly, K., P. Bente and J. Dau. 2007. Response of Overwintering Caribou to Burned Habitat in Northwest Alaska. *Arctic* 60:401-410.

Joly, K., R. R. Jandt, C. R. Meyers, and M. J. Cole. 2007. Changes in vegetative cover on Western Arctic Herd winter range from 1981-2005: potential effects of grazing and climate change. *Rangifer Special Issue* 17: 199-207.

Joly, K., R. R. Jandt, and D. R. Klein. 2009. Decrease of lichens in Arctic ecosystems: the role of wildfire, caribou, reindeer, competition and climate in north-western Alaska. *Polar Research* 28: 433–442.

Laperriere, A. J., and P. C. Lent. 1977. Caribou feeding sites in relation to snow characteristics in northeastern Alaska. *Arctic* 30:101-108.

Lawler, J. J., S. L. Shafer, D. White, P. Kareiva, E. P. Maurer, A. R. Blaustein, and P. J. Bartlein. 2009. Projected climate-induced faunal change in the western hemisphere. *Ecology* 90: 588-597.

Nowacki, G., P. Spencer; M. Fleming, T. Brock and T. Jorgenson. 2001. Ecoregions of Alaska: 2001. U.S. Geological Survey Open-File Report 02-297.

Pruitt, W. O. 1959. Snow as a factor in the winter ecology of the barren-ground caribou. *Arctic* 12: 159-179.

Rupp, T. S. , M. Olson , J. Henkelman , L. Adams , B. Dale , K. Joly , W. Collins , A.M. Starfield . 2006. Simulating the influence of a changing fire regime on caribou winter foraging habitat. *Ecol. Applications*. 16: 1730-1743.

Rupp, T. S. and A. Springsteen. 2009. Summary Report for Kanuti National Wildlife Refuge. Projected Vegetation and Fire Regime Response to Future Climate Change in Alaska. Scenarios Network for Alaska Planning (SNAP), University of Alaska, Fairbanks. Fairbanks, Alaska.
http://www.snap.uaf.edu/resource_page.php?resourceid=9

Schaefer, J. A. and W. O. Pruitt. 1991. Fire and Woodland Caribou in Southeastern Manitoba. *Wildlife Monographs* No. 116, 39 pp.

Telfer, K. S. and J. P. Kelsall. 1984. Adaptation of some large North American mammals for survival in snow. *Ecology* 65:1828-1834.

Thomas, D. C., S. J. Barry and G. Alaie. 1996. Fire-caribou-winter range relationship in northern Canada. *Rangifer* 16:57-67.

USFWS. 1993. Kanuti National Wildlife Refuge Annual Narrative Report for calendar year 1993. U. S. Fish and Wildlife Service, Fairbanks, Alaska. 77pp.

USFWS. 2008. Revised Comprehensive Conservation Plan Kanuti National Wildlife Refuge. U. S. Fish and Wildlife Service, Fairbanks, Alaska. 217 pp.

USFWS. 2007. Kanuti Fire Management Plan. US Fish and Wildlife Service, Kanuti National Wildlife Refuge, 349 pp.

Appendix 1

Photographic Standard for Extensive Caribou Cratering Activity, Kanuti National Wildlife Refuge, Alaska.



Photographic Standard for Moderate Caribou Cratering Activity, Kanuti National Wildlife Refuge, Alaska.



Photographic Standard for Low Caribou Cratering Activity. Kanuti National Wildlife Refuge,
Alaska.

